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# EFFECTS OF CLIMATE CHANGE AND GENETIC PROGRESS ON PERFORMANCE OF WHEAT CULTIVARS, DURING THE LAST TWENTY YEARS IN SOUTH ROMANIA

**Cristina Marinciu, Pompiliu Mustăţea, Gabriela Şerban, Gheorghe Ittu, Nicolae N. Săulescu**

National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania
E-mail: cristinamarinciu77@yahoo.com

## ABSTRACT

**Climate change effects on wheat performance have been already detectable during the last twenty years in many parts of the world. We analysed results obtained at Fundulea, in South Romania, in long term yield trials with wheat cultivars, in which the same historical control cultivar (Bezostaya 1) was maintained every year. Our purpose was to detect trends in grain yield, heading date and height, and their possible association with weather trends.**

**During last two decades (1991-2012), a significant increase in temperature both during vegetative growth and grain filling was observed, while rainfall presented only a slight decrease, but large year to year variations. During the analysed period, yields of the historical wheat control showed a reduction trend, which averaged –32 kg $ha^{-1}$ $year^{-1}$, while the average yield of most recently released cultivars showed an increasing trend of +40 kg $ha^{-1}$ $year^{-1}$. This suggests that genetic progress reflected in the release of new wheat cultivars was able to counteract the negative effect of climate change seen on yield of the historical control cultivar. The yield difference between the most recently released cultivars and the historical check showed a significant increasing trend of 69 kg $ha^{-1}$ $year^{-1}$. The increased temperature was associated with significantly earlier heading date, both for the historical check, Bezostaya 1 and for newly released cultivars, but no significant correlation between heading date and grain yield was observed. The rainfall amount summed over the months of April to June had a positive but not significant influence on plant height, but was significantly correlated with grain yield, both in the historical check Bezostaya 1 and in newly released cultivars.**

**The ability of new cultivars to compensate for the negative impact of climate change might have been related to their earliness and to lower sensitivity of yield to maximum temperatures during grain filling. These characteristics deserve attention as possible breeding objectives for further adaptation to future climate changes.**

**Key words:** climate change, genetic progress, wheat.

## INTRODUCTION

Concerns about the vulnerability of agricultural production to climate change are increasing. During the last two decades, climate changes have been shown to impact on crop development and yields (Estrella et al., 2007; Liu et al., 2010; Lobell and Asner, 2003; Zhang et al., 2013).

An increase of the mean temperature by 1°C led to yield decreases of up to 11% for winter wheat (Trnka et al., 2012). The negative effects of increasing temperature and drought on grain yield were most pronounced in the districts that are currently the warmest and driest. Asseng et al. (2011) found that the variations in average growing-season temperatures of ±2°C in the main wheat growing regions of Australia can cause reductions in grain production of up to 50%. Most of this can be attributed to increased leaf senescence as a result of temperatures >34°C. Nadine et al. (2010) found that in France the genetic progress has not declined but it was partly counteracted, from 1990 on by climate change, which in general was unfavourable to cereal yields in temperate climates, because of heat stress.

Tao et al. (2006) studied the impact of climate changes on rice phenology and yield using correlation analysis with data collected at experimental stations from 1981 to 2000. They showed that changes in temperature over past decades had accelerated rice phenological

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development and decreased rice yields. At the same conclusion arrived Parry (1990) who stated that the temperature determined the potential length of the growing seasons, and generally had a strong effect on the timing of developmental processes and on rates of expansion of plant leaves.

The latter, in turn, affected the time at which a crop canopy can begin to intercept solar radiation and thus the efficiency with which solar radiation was used to make plant biomass. Liu et al. (2010) showed that, if varietal effects were excluded, warming during vegetative stages would lead to a reduction in the length of the growing period, generally leading to a negative impact on crop production. However, adoption of new crop varieties was able to compensate for the negative impact of climatic change. The varietal changes helped stabilize the length of pre-flowering period against the shortening effect of warming and, together with the slightly reduced temperature in the post-flowering period, extended the length of the grain-filling period.

Parry (2007) concluded that climate change would generally reduce production potential and increase risk of hunger. Development of successful strategies to alleviate the adverse impact of climate change on crop production relies on understanding of interactions between climate and crop physiology, and presents a new opportunity for sustainable agriculture (Liu et al., 2013).

This paper attempts to estimate the effects of climate change and of genetic progress, by analysing the trends of yield, date of heading and plant height of one control cultivar that has been tested continuously in yield trials and of most recently released wheat cultivars, in South Romania, during the period 1991-2012.

## MATERIAL AND METHODS

Yields and some traits, such as heading date and height were analysed in historical check Bezostaya 1 and in newly released cultivars, tested during the period 1991-2012, in yield trials at Fundulea, in South Romania (latitude 44° 30’ N, longitude 24° 10’ E). The period 1991-2012 was chosen for analysis in this study because previous analysis showed that during the previous period for which data were available (1969-1990) yields of the historical control showed no diminishing trend (data not shown).

To estimate the behaviour of newly released cultivars, for each year, average data for the 3 to 5 most recently released cultivars was used, as follows:

- for the years 1991 and 1992 the average of cultivars Fundulea 133, Flamura 85 and Fundulea 4;
- for the years 1993-1999, the average of cultivars Flamura 85, Fundulea 4, Rapid and Dropia;
- for the year 2000 the average of cultivars Flamura 85, Fundulea 4, Rapid, Dropia and Boema;
- for the year 2001 the average of cultivars Dropia, Boema and Crina;
- for the years 2002 and 2003 the average of cultivars Dropia, Boema, Crina and Delabrad;
- for the year 2004 the average of cultivars Boema, Crina, Delabrad, Dor and Faur;
- for the years 2005 and 2006 the average of cultivars Delabrad, Dor, Faur, Glosa and Gruia;
- for the year 2007 the average of cultivars Faur, Glosa, Gruia and Izvor;
- for the years 2008 to 2012 the average of cultivars Glosa, Gruia, Izvor, Litera and Miranda.

Weather data for this period were collected from the meteorological station of the Institute, located in close vicinity of the yield trials.

We used correlations and regressions to estimate trends and associations of plant traits and weather data.

## RESULTS

### Observed trends in weather characteristics during 1991-2012

Several trends in weather characteristics were observed during the period 1991-2012. A significant increase was found in the maximum temperatures averaged over the months of March to May, which roughly corresponds to the period of wheat vegetative growth (Figure 1). The regression line indicates an increase of about 6ºC in the average of maximum temperatures during the vegetative growth, during the last twenty years.

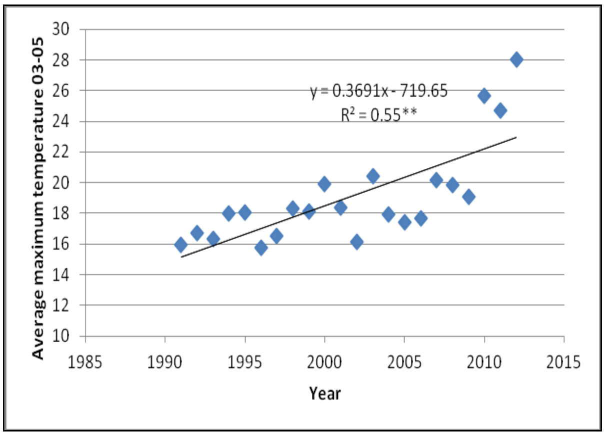

*Figure 1*. Evolution of maximum temperatures averaged over the months of March to May, during the period 1991-2012

A similar trend was found in the maximum temperatures averaged over the months of June and July, approximately corresponding to the grain filling and ripening period (Figure 2).

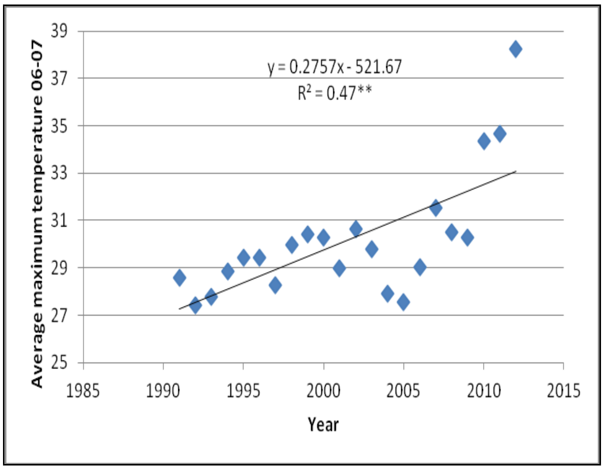

*Figure 2*. Evolution of maximum temperatures averaged over the months of June to July, during the period 1991-2012

The rainfall amount summed over the months of April to June, corresponding to the intense vegetative growth period, anthesis and grain filling, showed large fluctuations from one year to another, but a relatively small diminishing trend is visible (Figure 3).

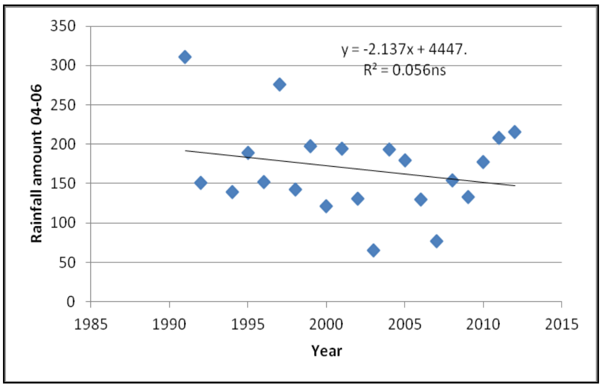

*Figure 3*. The evolution of rainfall amount summed over April to June, during 1991-2012

## Observed trends in wheat traits during 1991-2012

During the analysed period, yields of the historical wheat control Bezostaya 1 showed a reduction trend which averaged –32 kg ha$^{-1}$ year$^{-1}$, while the average yield of most recently released cultivars showed an increasing trend of +40 kg ha$^{-1}$ year$^{-1}$ (Figure 4). This suggests that genetic progress reflected in the release of new wheat cultivars counteracted the negative effect of climate change seen on yield of the historical control cultivar. Regressions suggest that during the twenty years of study yields of the long term check decreased by about 600 kg ha$^{-1}$, corresponding to about 75 kg ha$^{-1}$ per 1ºC increase in the maximum temperatures averaged over the months of March to May. During the analysed period, heading date of both the long term control and newly released cultivars had a significant trend towards earlier heading, by -0.34 and -0.47 days year$^{-1}$ respectively (Figure 5).

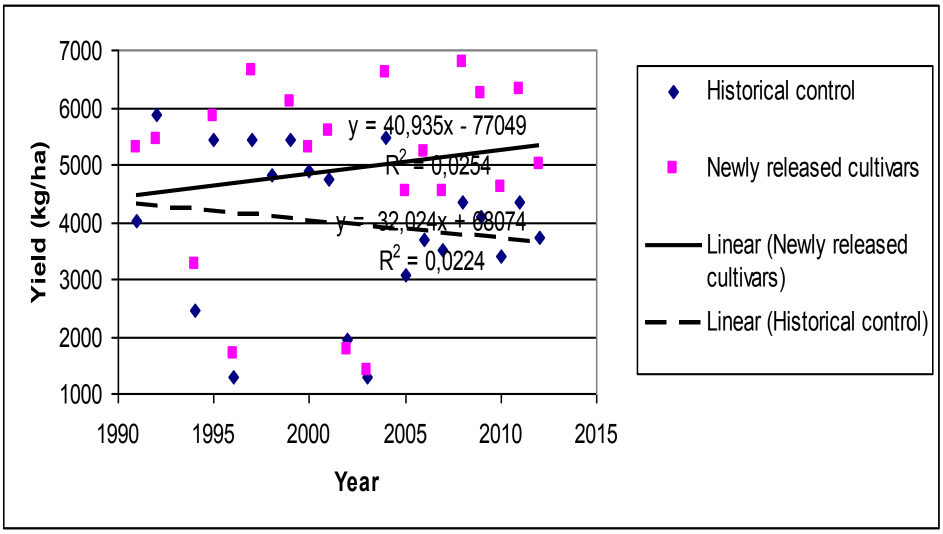

*Figure 4.* Trends of yield in the historical control cultivar and in recently released cultivars, during 1991-2012

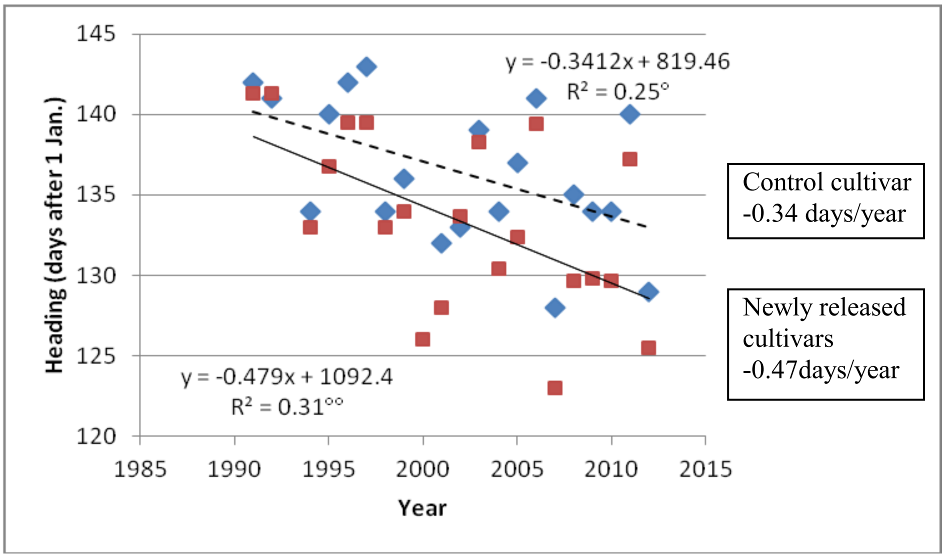

*Figure 5.* Trends of heading date in the historical control cultivar and in recently released cultivars, during 1991-2012

The newly released cultivars headed earlier than Bezostaya 1, and the difference increased from about 1.5 days at the beginning of the period, to almost 4 days at the end. Therefore, the slightly higher trend towards earlier heading in the new cultivars could be explained by the fact that some of the most recently released cultivars were genetically earlier than the previous ones, and consequently the observed trend included both the effect of climate change and of genetic progress.

Height showed a very large year to year variation, but no definite trend in time could be detected during the analysed period (Figure 6). The newly released cultivars, which were all semidwarfs, were shorter than the historical check, and the difference remained almost constant during the analyzed period.

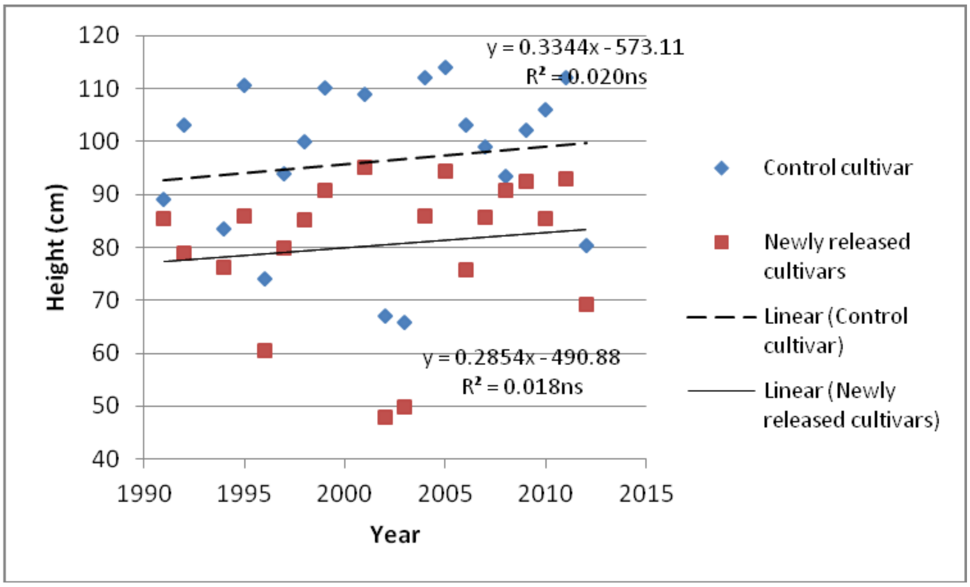

*Figure 6.* Trends of height in the historical control cultivar and in recently released cultivars, during 1991-2012

### Relationship between characteristics of the analysed wheat cultivars

Earlier heading of the control cultivar Bezostaya 1 was accompanied by only a very small, non-significant yield reduction, while in recently released cultivars earlier heading was accompanied by slightly higher yields (Figure 7). This might be due to the fact that some of newer, higher yielding cultivars were also genetically earlier heading.

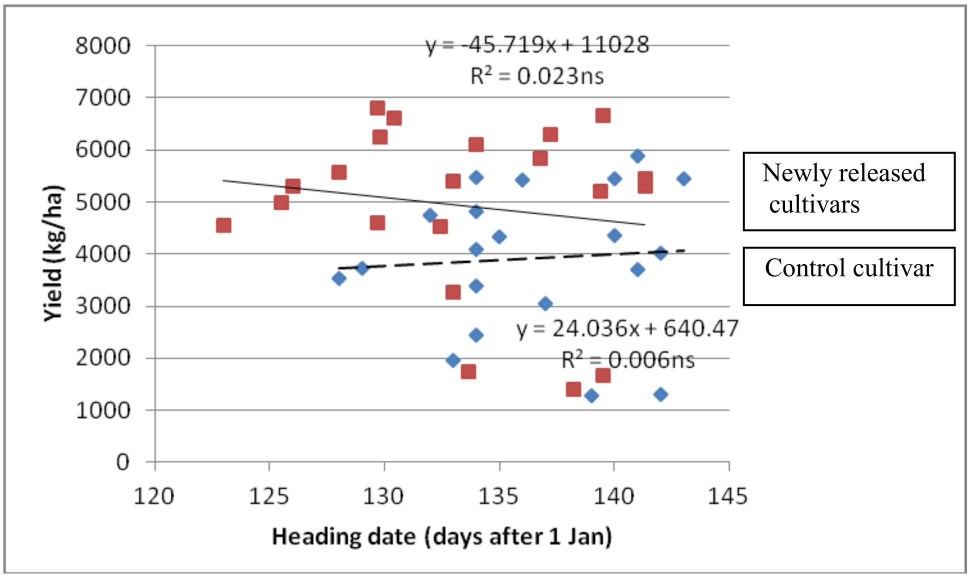

*Figure 7.* Relationship between heading date and yield, during 1991-2012

Relationship between height and grain yield was very significant both for historical check and newly released cultivars, suggesting a high dependence of grain yield on vegetative growth (Figure 8).

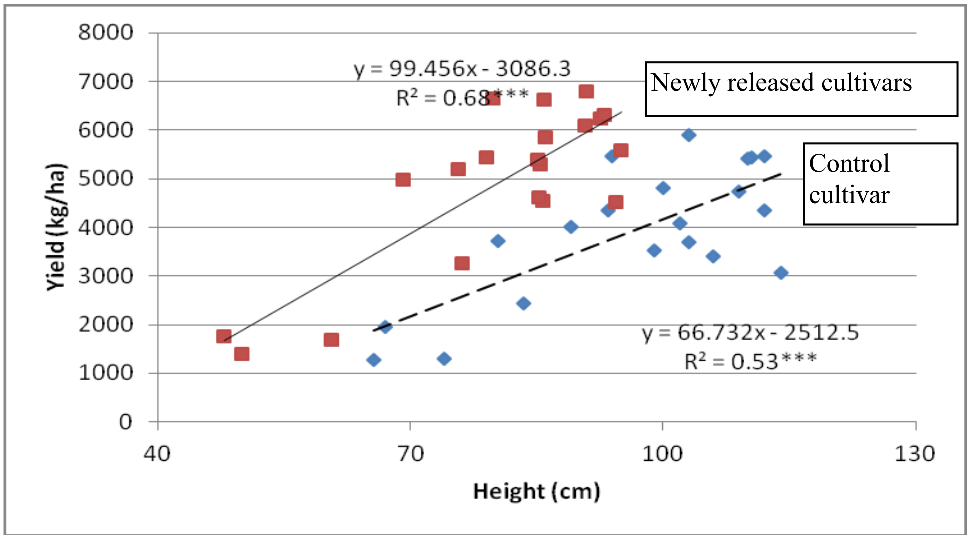

*Figure 8*. Relationship between height and yield, during 1991-2012

### Relationship between weather characteristics and performance of wheat cultivars

The increase of maximum temperature during the vegetative growth stage led to earlier heading date (Figure 9). However, as shown earlier (Figure 7), in contrast with findings of other authors (Liu et al., 2010), earlier heading date was not reflected in yield reduction. It is possible that besides having a negative impact on vegetative biomass accumulation, earlier heading contributed to avoiding high temperatures during the grain filling and therefore to longer grain filling duration.

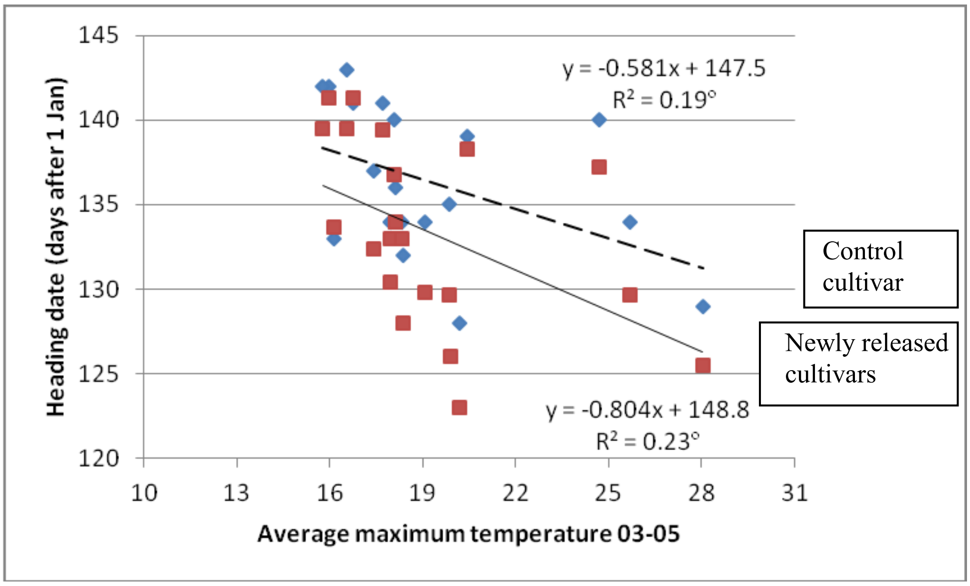

*Figure 9*. Relationship between average maximum temperature during the vegetative stage and heading date, during 1991-2012

The yields of newer cultivars seemed to be less influenced by the maximum temperatures during the grain filling period, in comparison with Bezostaya 1, which showed a trend of reduced yields (Figure 10).

A positive, but not significant, association between rainfall amount summed over the months of April to June and height was observed for both control cultivar and newly released cultivars (Figure 11).

Rainfall amount cumulated during the growing period significantly influenced yields, especially in the new cultivars (Figure 12).

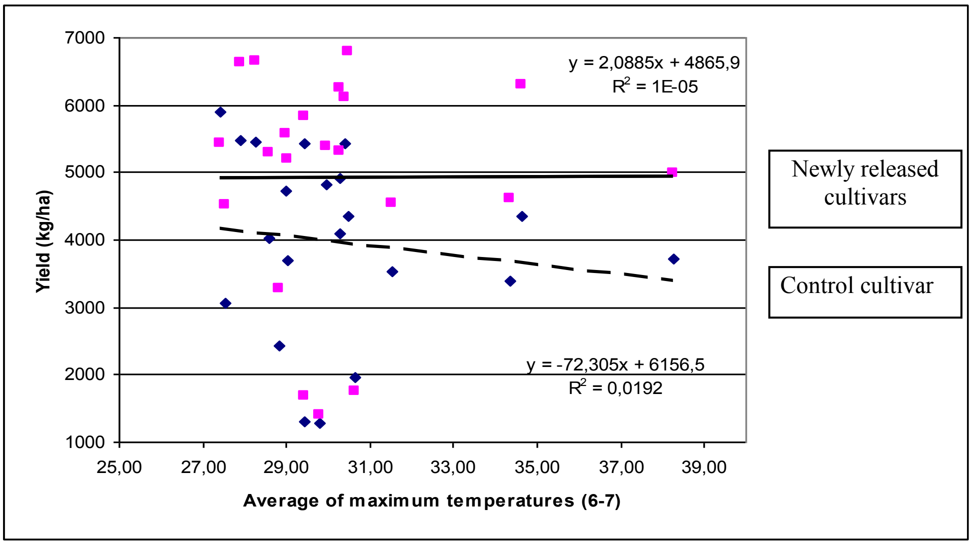

*Figure 10*. Relationship between the average of maximum temperatures during June-July and yields of Bezostaya 1 and of newly released cultivars, respectively

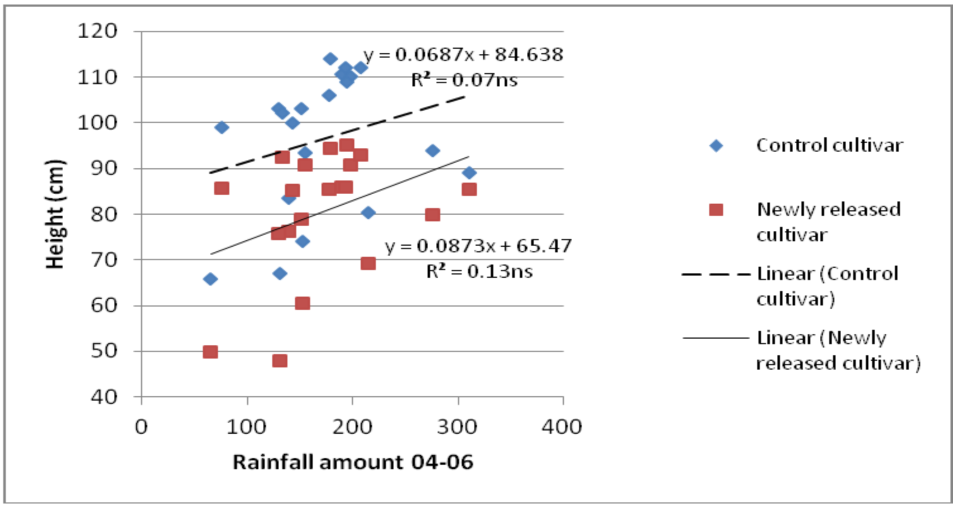

*Figure 11*. Relationship between rainfalls summed over the months of April to June and height, during 1991-2012

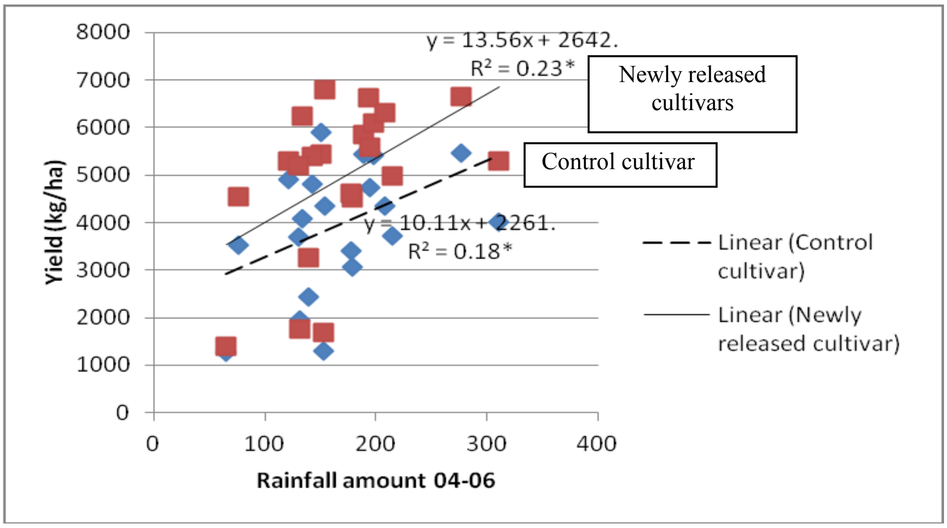

*Figure 12*. Relationship between rainfall amount summed over from April to June and yield, during 1991-2012

## DISCUSSION

Only three climate indexes were used in our study, and these provide only a very approximate description of weather conditions that influenced wheat growth and yield. Averages and sums often mask the true influence of the studied factor. Additionally, for reasons of simplicity, we calculated climate indexes for fixed periods, not taking into account the variation in growth and grain filling timing from one year to another. However, even these approximate indices indicated that the trends in temperatures and rainfall observed during the last twenty years were reflected in corresponding trends of yield, heading date or height.

The trend towards higher temperatures during the vegetative stage was reflected in a significant trend towards earlier heading, but this had only a very small negative influence on yields of Bezostaya 1, while in newly released cultivars the effect of higher temperatures was covered by the effect of genetic progress in earliness.

The yield difference between newly released cultivar and historical check, increased significantly during the analysed period, on average by 69 kg ha$^{-1}$year$^{-1}$, and this could be considered an estimate of the genetic progress over Bezostaya 1. However, as seen, part of this genetic progress was annihilated by climate changes (Figure 13).

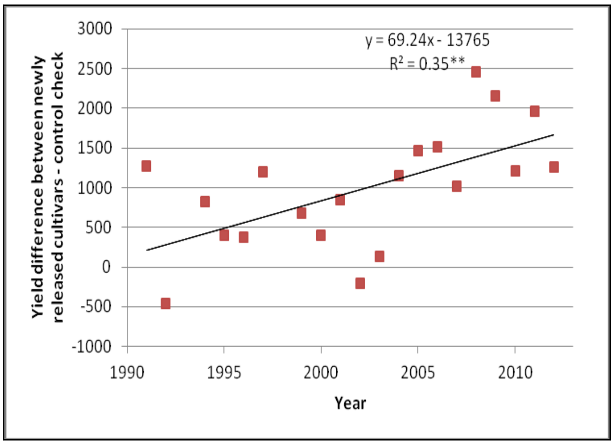

*Figure 13.*Yield difference between newly released cultivars and Bezostaya 1, during 1991-2012

The trends observed in plant traits and their association with weather indices suggest that the ability of new cultivars to compensate for the negative impact of climate change might be related to their earliness and to lower sensitivity of yield to maximum temperatures during grain filling. These characteristics deserve attention as possible breeding objectives for further adaptation to future climate changes.

## CONCLUSIONS

During the period 1991-2012, at Fundulea in the Romanian Danube plain, maximum temperatures averaged over the months of March to May and June to July increased significantly, while rainfall showed large year to year variation, but only a small and not significant decreasing trend.

During the same period, yields of a long term check showed a decreasing trend (on average by -32 kg ha-1 year-1), but genetic progress was able to compensate for the negative impact of climate change, and produce a positive trend (on average by + 40 kg ha-1 year-1).

Yields of both the historical check and newly released cultivars were highly dependent on rainfall, and reflected the large year-to-year variation of precipitation.

Grain yields were significantly associated with plant height, suggesting a strong dependence on biomass accumulation;

A significant trend towards earlier heading, associated with higher temperatures during the vegetative stage was observed. However, this trend was not reflected in lower grain yields, probably because earlier heading led not only to reduced biomass, but also to longer grain filling duration.

Results suggest that earliness and lower sensitivity to temperatures during grain filling period, might have contributed to the ability of new cultivars to counteract the effect of climate change. Therefore these characteristics should be considered potential objectives in further breeding for reducing the impact of climate change.

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